Indicators of strangulation in medico-legal assessments: A scoping review

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N. Heldring: Conceptualization, Formal analysis, Investigation, Supervision, Writing - original draft & editing, **D.Krona:** Conceptualization, Investigation, Writing - review & editing. **E.Rudd:** Conceptualization, Investigation, Writing - review & editing.

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Abstract

This scoping review aims to synthesize the existing knowledge on third-party strangulation, both fatal and non-fatal, with an emphasis on identifying key physical and symptomatic indicators, their prevalence, and the critical point and circumstances surrounding such incidents. A total of 19 articles addressing homicidal fatal strangulation and 34 articles addressing non-fatal strangulation were retrieved. The majority of the strangulation victims studied were below 40 years of age, with a predominance of women. The findings from the reviewed studies highlight the complex and multifaceted nature of strangulation, both in consensual and non-consensual contexts. Strangulation events range from no injury to severe injuries and death. Objective findings are common but not universal, with their detection influenced by study design, victim selection, and the time between the assault and examination. Fatal cases without external injuries (up to 16%) highlight the need for caution in assessing severity in nonfatal cases of alleged strangulation based solely on visible external signs. Most studies of non-fatal strangulation focus on victims of intimate partner violence or sexual assault and highlight that strangulation is a common feature of such violence. Emerging evidence suggests that repeated strangulation events has potential effects on brain function, though further research is needed. The exact critical threshold where strangulation becomes life-threatening is not possible to define and call for a consensus approach in medico-legal assessments. These findings underline the importance of detailed medical records capturing subjective findings, along with high-quality photographic or radiographic documentation, combined with detailed police reports outlining the sequence of events, for medico-legal implications of such cases.

Keywords: choking, asphyxia, postmortem, forensic medicine, autopsy, biomarker

Introduction

Strangulation, a form of asphyxia caused by external compression of the neck, is a critical concern in forensic medicine due to frequently inconclusive findings, which add to the complexity of assessing the event and evaluating its potential threat to life. The most common medico-legal investigations of asphyxia homicides include manual and ligature strangulation (1-3). Non-fatal strangulation is increasingly being recognized as a significant factor in a consensual sexual setting as well as in domestic violence, sexual assault and other criminal contexts (4, 5) Strangulation violence therefore represents a critical, yet possibly under-recognized form of assault, with significant implications for victim health and legal outcomes.

From a medico-legal perspective, in fatal as well as non-fatal cases it is of importance to characterize findings or lack of findings that may depend on the mechanism, as well as the force and duration of compression. Strangulation operates through a dual mechanism, with hypoxia resulting either from vascular compression, which reduces cerebral blood flow and thereby oxygen delivery to the brain, or from airway obstruction (6). These mechanisms can be categorized as vascular and airway strangulation, respectively, although they coexist to varying degrees during strangulation events and are inseparable in a medico-legal assessment. Compared to vascular strangulation, airway strangulation alone may preserve the cerebral circulation for a period of time, most likely resulting in a delayed onset of unconsciousness. Another mentioned mechanism involved in strangulation, though contested, is reflexive cardiac arrest, resulting in a lack of blood flow to the brain, triggered by stimulation of pressure receptors in the neck vasculature (6-8). In non-fatal cases, a significant concern is that victims may experience neurological, cognitive, and psychological consequences, regardless of visible injuries. Variations in the force applied in the strangulation, duration of compression, and the method used result in a wide spectrum of injury severity, ranging from

significant trauma to no detectable injuries in many cases. Nevertheless, investigations of injuries associated with strangulation are often challenging due to the involvement of additional types of violence, making the determination of the origin of an injury more difficult. The difficulty in diagnosing and documenting fatal and non-fatal strangulation injuries emphasizes the need for a literature review to improve assessments and reporting for accurate medico-legal outcomes. This scoping review aims to synthesize the current body of knowledge on both fatal and non-fatal strangulation and focus on highlighting relevant physical and symptomatic indicators and the occurrence of these, together with addressing critical points for life threat and circumstances relevant to the injuries. Strangulation is heterogenous term in the literature, where the focus in this work has been on strangulation as pressure applied to the neck, restricting blood flow, or respiration, but where the force is applied by another person and not from the victims own body weight. This includes both manual and ligature strangulation. By examining existing literature, this review seeks to offer an updated knowledge framework for medico-legal implications of such cases.

Methods

Search strategy

A literature search was performed in the following databases: Medline, Embase, Web of Science and CINAHL. The search strategy was developed in Medline (Ovid) in collaboration with librarians at the Karolinska Institutet University Library. For each search concept Medical Subject Headings (MeSH-terms) and free text terms were identified. The search was then translated, in part using Polyglot Search Translator (9), into the other databases. Databases were searched from inception. The strategies were proofread by another librarian prior to execution. De-duplication was done using the method described by Bramer et al (10).

One final, extra step was added to compare DOIs. The full search strategies for all databases are available in supplementary Table 1-4.

Selection

The selection of articles was based on 1) full-text article was electronically available in English, 2) information on findings for strangulation is stated and included studies published up to 16 April 2024.

Study evaluation

Original studies were evaluated using SPICOT (Study design, study population, intervention/exposure, controls/comparisons/index test, outcome and timespan) a framework to systematically assess both scientific evidence and risk of bias of the forensic literature (11). Screening was conducted by two researchers to ensure that only studies fulfilling established scientific criteria were selected to form the knowledge base in this review. All studies were assessed in each category described to determine a combined level of evidence and risk of bias (categorized with low scores (0–9 points), medium (10–16 points), or high (17–20 points)). This scoring process was carried out by two researchers. In case of differing assessments, consensus discussions were held to decide final score. Those scoring SPICOT-low and SPICOT-medium, were additionally assessed by a third separate independent researcher. If variations in scores impacted SPICOT classification, consensus discussions were held between the three researchers to decide final score. Studies that all researchers identified as having a SPICOT-low (low level of evidence and an identified risk of introducing bias) were excluded.

Synthesis of the results

The studies were collated and summarized in two tables based on the population examined, deceased (Table 1) and living (Table 4). Further, the studies were grouped based on focus category for deceased (Table 2) and living (Table 5). Studies examining fatal strangulation (Table 2) are categorized based on pathological findings whereas the studies examining non-fatal strangulation are classified according to circumstances or methods (Table 5). The reported and frequency of findings in fatal (Table 3) and non-fatal strangulation (Table 6) were summarized.

Results

After screening and evaluation, this review included 19 original studies focused on diseased populations and 34 original studies on living populations (Fig. 1). In addition, 12 other relevant sources of information were included.

Fatal strangulation

A total of 19 articles addressing homicidal fatal strangulation were retrieved (Table 1). The focus of eight of these studies was on supporting evidence of strangulation (12-19), while six studies concentrated on describing external and internal findings (3, 20-24). Five studies aimed to investigate hyoid, thyroid, and cricoid fractures as well as soft tissue haemorrhages (22, 25-28) associated with strangulation, and one study focused on describing the competing causes of death in cases with strangulation (29) (Table 2). The age of the studied cases ranged from 0 to 93 years with a mean age of 37 years. The majority of the cases were women, 548 cases versus 202 men (Table 1).

External findings

An external finding that generally has been considered to be of high significance in connection to strangulation is petechial haemorrhages of the face or conjunctiva. The finding was reported in 95% of cases in both the Hlvaty et al and Härm et al studies (23, 29). In contrast, other studies observed lower rates, with Harruff et al (24) reporting an incidence of 83%, and Tellwar et al (20) reporting 75%, though the latter specifically referred to "sub-conjunctival hemorrhage". Other findings, like facial congestion, showed significant variation across studies, from 17% (3, 20) up to 100% (29) (Table 3).

Internal findings

Fractures of the laryngeal structures are frequently reported, though some studies detail individual fractures, while others group them together or describe them collectively as fractures of for instance "either the hyoid bone or the thyroid cartilage".

Ma et al reported hyoid fractures in 12% of cases of fatal strangulation, thyroid cartilage fractures in 3%, and fractures of both in 1% (22). On the other end, Thomsen et al reported hyoid fractures in 28% of cases and thyroid fractures in 52% (3). Cricoid fractures are more rarely reported. Godin et al reported neck structure fractures in 23% of suicidal hanging cases while the cricoid cartilage was always intact, but in homicidal non-hanging strangulations cricoid fractures were found in approximately 14% of the cases (26). Hence, Godin et al suggested from his study that when found, cricoid fractures should make the examiner highly suspicious of homicide (26). Thomsen et al reported cricoid fractures in 19% of manual or ligature homicidal strangulation (3). Among the included studies, the incidence of neck structure fractures ranged from 16% (22) up to 65% (26) of the cases.

Our review found only three studies (24, 27, 29) that report data from cases without any external and/or internal findings (Table 3). Hlvaty et al. reported that 2 out of 19 cases (11%) of manual vascular strangulation deaths showed no external or internal findings, except for

facial congestion (29). Harruff et al. noted that 16% of cases lacked external neck injuries, while nearly 80% only exhibited neck injuries like bruising or abrasions (24). Maxeiner et al reported that “less than 20%” of homicidal ligature strangulations had no internal injuries (27).

Three studies report examined toxicology for ethanol and/or other drugs (22, 23, 29) in cases of fatal strangulation. A positive toxicology was reported in 63% of cases by Hlavaty et al (29) and 10% of cases by Ma et al (22). Härm et all documented positive ethanol in 44% and positive drug toxicology in 11% of all cases (23). Hlavaty highlighted a higher prevalence of cocaine use in the cases in fatal strangulation cases compared to homicides in general (29), while Härm noted the suspicion that drugs may have been used in two cases to subdue the victims prior to strangulation (23).

Biomarkers and pulmonary or brain pathophysiology

Attempts have been made to identify pathophysiological findings in the lungs or brain that could support the occurrence of strangulation, its severity, or potentially as the cause of death (13, 14, 16, 17). Klysner et al aimed to determine the presence of abnormal distension of alveolar airspaces in fatal strangulations and whether this could be used to support the diagnosis of strangulation (14). The authors found that the alveoli are larger in the strangulation cases compared to age and gender matched controls who died from natural causes, and that this difference is statistically significant (14). However, they also point out that the analysis must be conducted in an objective and quantifiable manner to prevent subjective bias in diagnostic support. Efforts to differentiate between deaths due to strangulation and acute cardiac events have included examining the expression levels of aquaporin 5 (AQP5) in the lungs (17). The authors identified distinct differences in pulmonary molecular pathology among the studied causes of death, noting that AQP5 levels were

suppressed in cases of smothering and choking compared to strangulation, sudden cardiac death, and acute brain injury death (17). However, the underlying mechanism for this observation remains unclear.

Heat shock proteins have been studied as post-mortem markers for vital reactions by assessing local and systemic responses to various forms of trauma and stress (30). In the context of brain pathophysiology, Quan et al. investigated cases of acute asphyxiation and demonstrated that severe fatal stress in acute mechanical asphyxiation and drowning induces increased intranuclear ubiquitin immunoreactivity in neurons of the midbrain (16). Moreover, Li et al showed a decrease in intact hippocampal astrocyte numbers in mechanical asphyxiation based on S100 and GFAP staining, together with an increase in serum S100B that were closely related to the severity of conjunctival petechial haemorrhage and fracture(s) of the hyoid bone and/or thyroid cartilage in asphyxia due to neck compression (13).

With regard to supporting evidence, post-mortem biochemistry has been a focus of research for many years, with blood and vitreous fluid analyses becoming established components in the investigation of deaths. Biomarkers are utilized in forensic medicine to assess conditions like chronic alcoholism, diabetes, infection, dehydration, hypothermia, and anaphylactic shock. Palmiere et al investigated and also observed a marked increase in thyroglobulin, total T3, and free T3 concentrations in blood samples taken from sites near the thyroid gland in a limited number of individuals (n=12) who had been strangled (12). The study indicated a good postmortem stability of thyroglobulin, calcitonin, and parathyroid hormone levels, while total and free T4 levels decreased, and total and free T3 concentrations increased. The authors also highlight instances of false negative results and conclude that a single laboratory test has limited diagnostic reliability (12).

One research group has focused on developing experimental models simulating manual strangulation and has confirmed the correlation between the force required to fracture the hyoid bone and age (31) as well as suggested simulation models to predict behaviour of hyoid bone or thyroid cartilage when subjected to strangulation (32, 33).

Non-fatal strangulation

A total of 34 articles addressing non-fatal strangulation (NFS) were retrieved (Table 4). The vast majority of the articles described individuals who were victims of intimate partner violence (IPV) and/or sexual assault (SA), five described strangulation in a consensual sexual setting while the circumstances surrounding the strangulation incident was not specified in detail in ten studies (Table 5). The median age of individuals in the studies, excluding Linkletter et al. (34), was predominantly under 40 years, with the majority being women (Table 4). The study by Linkletter et al., evaluated sixty-five videos on recreational partial asphyxiation found on the video sharing website YouTube and approximately 54% of participants in "the choking game" were estimated to be between 12 and 18 years old, while the remainder were assessed as adults (34) (Table 4). The goal of this internet challenge phenomenon was to achieve a brief euphoric state caused by cerebral hypoxia.

Frequency of non-fatal strangulation

Non-fatal strangulation has been reported to occur in consensual sexual settings as well as in a setting of domestic violence and/or sexual assaults. The study conducted by Hebernick et al (35) examined the context of consensual sexual activities among a campus population, a cohort of college students with a mean age of 22.2 years (ranging from 18 to 67 years). Among the undergraduates, 37.1% reported having choked (corresponds to strangulated in this study) someone at some point, while 42.1% reported having been choked. Among graduate students, 27.6% reported having choked someone, and 32.1% reported having been

choked (35). In an Australian context, Sharman et al. conducted cross-sectional online surveys among a large population aged 18–35 years to determine the prevalence of strangulation during sex (36). They found that 57% of participants reported having experienced sexual strangulation at some point. Further, the authors pinpointed that a large proportion of participants thought prior consent for sexual strangulation was an acceptable form of consent for future choking activities. Those strangling did more frequently not ask for, or discuss, strangulation before it occurred during sex (36). The selected studies conducted within an IPV or SA context were identified based on an NFS focus, which consequently results in a high prevalence of NFS among these victims (Table 5).

Objective signs of strangulation

Objective signs observed for non-fatal strangulation includes petechial haemorrhages in the face/neck, mouth or eyes, bruising, erythema, abrasions and swelling (Table 6.)

The observation of petechial haemorrhage in the face/neck or eyes in strangulation cases varies between 1% (37) up to 27-28% (38, 39) (Table 6). The studies reporting the highest percentage of petechial haemorrhages were of a prospective design and examined a limited population of 14 or 63 individuals (39) (38). Yen et al (39) compared external findings to internal findings using radiology in patients subjected to non-fatal strangulation in a prospective study and found petechial haemorrhages in 28% of the examined individuals. The fact that petechial haemorrhages after strangulation are considered to be a sign of severe neck compression (40) in combination with the fact that radiology exams often are reserved for patients with suspected internal injuries, may serve as an explanation for the higher percentage in this study. Reckdenwald et al (38) examined forensic documentation of non-fatal strangulation victims and the majority of these (75%) were examined within 24 hours after the alleged assault which increase the chance of detecting petechial haemorrhages. In the

retrospective studies, including larger cohorts (142 and 328), petechial haemorrhages are described in 4.9% (41) and 6% (42).

Bruising on the neck is described in several studies (23, 35, 37, 38, 40-50) and in up to 68% of examined individuals (46) (Table 6). Four of these studies compared external findings with radiological exams (39, 41, 44, 48). According to White et al., visible indicators (localized to the neck and above) associated with non-fatal strangulation diminish over time, decreasing from detectable in 53% within the first 48 hours to 0% after five days (45).

Subjective signs of strangulation

Reported subjective symptoms in non-fatal strangulation include, cognitive effects, dizziness, visual or hearing defects, voice changes, pain, dysphagia and dyspnoea and to some degree loss or alterations of consciousness (Table 6). These signs are reported as experienced either during or after the strangulation event.

Loss or alteration of consciousness has been reported in approximately 1% (23) to 55% (34) of individuals studied in the context of IPV violence or SA (23, 34, 35, 37-45, 47-55), while dizziness has been reported in 8.9% to 72.1% of cases (35, 37, 42, 43, 47, 49, 53, 54) (Table 6). In a study of 142 strangulation victims, not specifically in an IPV/SA context, 47% of the individuals experienced loss of consciousness in connection to the event (41). In a consensual context, loss of consciousness is described in 2.6% of the study population, while any alteration in consciousness was been reported in 15.2% (35).

Hypoxia and the effects on the brain

The effects on the brain after strangulation events are examined in several studies (38, 50, 54, 56-58). Collectively these studies describe several symptoms in these women possibly relating to hypoxia, including dizziness, loss of memory, and cognitive problems (Table 6).

Structural brain differences have been demonstrated with magnetic resonance imaging in women who had been subjected to IPV and NFS compared to women from an IPV setting without NFS (59). Further, studies focusing on sexual choking events suggests that these repeated episodes are associated with neuroanatomic alterations, altered working memory and brain activation pattern as examined with high resolution anatomical magnetic resonance imaging and functional magnetic resonance (56-58).

Supporting evidence to the strangulation diagnose

Radiologic imaging

Several studies have investigated whether advanced radiologic imaging modalities, such as CT or MRI, might enhance the ability to detect subtle injuries in lethal or non-lethal strangulation victims (18, 39, 41, 46-48, 60, 61). Decker et al conducted an integrated study comprising a literature review and an analysis of cases identified from the state-wide centralized database in New Mexico to assess the role of post-mortem computed tomography (PMCT) in complementing autopsy for the evaluation of strangulation fatalities (18). The authors concluded that while PMCT serves as an effective tool for detecting subtle bony injuries in such cases, it should not be regarded as a substitute for traditional autopsy in instances of homicide (18).

Zuberi et al (41) investigated whether CT angiography of the neck could detect acute vascular injuries following strangulation. This retrospective study encompassed 142 cases of non-fatal strangulation and concluded that the diagnostic utility of this method in this population is limited (41). A recent study conducted on 116 cases of non-lethal strangulation, concluded that MRI should be preferred over CT for assessing strangulation-related injuries (62). The findings indicate that MRI offers superior accuracy compared to CT and in addition, avoids

the exposure of this typically young population to ionizing radiation (62). Over the last decade, several studies have indicated that MRI provide a useful objective proof supporting the forensic pathologists when evaluating the strangulation event (39, 44, 46-48, 61). Initially, studies focused on using radiologic signs to differentiate between life-threatening and non-life-threatening strangulation (39, 47, 61). From these studies, based on a limited population of non-lethal strangulation survivors, scoring systems to predict danger to life were suggested (39, 47, 61). The more recent MRI studies, have focused on evaluating the method in a living population to reveal internal injuries as supporting evidence in the assessments (44, 46, 48, 62). A common conclusion in these studies is that MRI examination of victims of suspected strangulation is useful and may reveal internal injuries also in cases without external findings and one of the studies indicate that injuries are detectable up to twelve days after the event (48). To further assess the potential utility of MRI in the evaluation of strangulation victims, a hypothesis was proposed that trauma-induced oedema in cervical muscles could result in asymmetrical muscle volumes as measured by MRI (60). However, this hypothesis was not supported by the findings of this case-control study (60).

Discussion

It is clear that strangulation is a common form of violence in IPV and SA based on included studies focusing on non-fatal strangulation (Table 5). However, even though the total proportion of men and women who have experienced strangulation in a sexual or a non-sexual context remains highly uncertain, the studies by Herbenick et al (35) and Sharman et al (36) are unique as they provide insight into young individuals experiences and the circumstances of strangulation in a consensual sexual setting. The authors of the US study (n=4242) found that a higher proportion of undergraduate and thereby younger students compared to graduate

students report choking in a sexual setting (35). The authors of the large Australian population study with volunteers from the general public aged 18-35 years (n=4702) found that 57% reported being choked in a sexual context and concluded that strangulation has become a mainstream sexual behaviour in young individuals (34). The worrying inconsistencies in the interpretation of consent (34) together with a possible lack of understanding of strangulation consequences highlight a potential massive problem. Even though the majority of the strangulations in the US college survey were described as consensual, 16% of the women described that they were scared during the choking event (33). A critical question is whether a person performing strangulation may have control of the situation as to whether the strangulation will escalate into a life-threatening or harmful act or not, and if signs of such an escalation can be identified. While no identified studies have specifically examined the point at which strangulation transitions from a non-life-threatening to a life-threatening act, evidence suggests that even a low amount of applied pressure can compromise critical functions of the throat's vital structures (30). Hence, force applied to the neck inherently poses a risk. Of note is that more than 33% of the Hebernick study population reported that they were unable to speak during the strangulation which may have implications in the use of so-called safe words in the practice of consensual strangulation (33). Additionally, in the Rossen study participants stated that even though they wanted to move, they were unable to do so during the asphyxia (63). However, strangulation practised in controlled sports environment is mainly accepted to represent a situation with a lower risk *i.e* martial arts competitions and practices (63). The controlled environments typically include a person overseeing the strangulation event and who is dedicated to interrupt, together with the presence of medical personnel.

The critical point at which strangulation becomes life-threatening is not possible to define, nor is the exact duration a chokehold must be maintained after unconsciousness to reach the point of no return. This point corresponds to a state in which respiration and circulation cannot be ensured without external intervention. Consequently, a national forensic medicine consensus was established in Sweden, recognizing unconsciousness caused by choking as a life-threatening condition (64).

Scoring systems to predict danger to life based on radiological findings have been proposed (39, 47, 61). However, applying such an approach is dependent on agreeing to the initial definition of life-threat. From a legal perspective, this has been addressed in certain countries, like England, Wales and Australia, by explicitly criminalizing strangulation. Regardless of the legal context, conducting a thorough examination and maintaining comprehensive documentation are essential for evaluating and describing findings and symptoms related to the strangulation event. Detailed medical records capturing subjective findings, along with high-quality photographic or radiographic documentation, combined with detailed police reports outlining the sequence of events, play a crucial role in facilitating the medico-legal assessment.

Alterations in consciousness and loss of consciousness together with pain, voice changes, vision changes, dizziness, difficulty in breathing, swallowing or speaking are subjective signs and symptoms mainly captured in self-assessments by non-fatal strangulation victims. These may vary from one individual to another depending on a variety of factors such as stress, anxiety, alcohol levels, medication and other types of co-occurring violence. However, loss of consciousness, vision changes and dizziness may be signs of cerebral hypoxia caused by the strangulation event.

Loss of consciousness is generally regarded as a sign of severe, life-threatening strangulation (38, 41). Loss or alteration of consciousness arises due to loss of oxygenated blood to the brain, something which can result from occlusion of the carotid arteries (blood strangulation) and obstruction to the airways (air strangulation). As demonstrated in a study from the 1940s that would be considered highly unethical by today's standards (63), loss of consciousness may occur within as little as 6 seconds due to cerebral hypoxia. In the study, participants had an inflatable cuff applied to their neck, which restricted blood flow to and from the brain without obstructing airflow. Subjects could voluntarily release the cuff; if they did not do so, the supervisor intervened to release the pressure upon loss of consciousness.

Interestingly, some participants who experienced loss of consciousness during the study denied losing consciousness, while others reported being unable to release the pressure despite their efforts. This may indicate that the actual incidence of loss of consciousness or effects of oxygen deprivation during strangulation may be higher than reported. Taking this into account, it may not be ruled out that assaulted individuals have a harder time reporting in detail to the police and other officials what has happened, and that they might be regarded as less credible in their accounts of the event leading up to a police report.

It is clear that strangulation is a common feature of the violence within IPV. However, the mixed violence profile in an IPV context can make it difficult to assign specific findings like loss of consciousness, bruising or other injuries to the strangulation in these situations. In the retrospective study conducted by Shields et al, which included 102 individuals subjected to IPV involving strangulation, 15% exhibited petechial haemorrhages (47). However, only 3 individuals reported strangulation as the sole mechanism of injury, while the majority of cases had been exposed to blunt force trauma in addition to the strangulation (47).

Plattner et al proposed a categorization of survived strangulation cases in three degrees of severity (light, moderate and severe) (38). These degrees could be argued to be confusing in a legal context since individuals exposed to non-fatal strangulation may not present with any findings or may suffer from delayed cognitive effects (55-57). The suggested categories were based on a known mode of strangulation (manual or ligature) and objective findings from a complete forensic medical examination performed shortly (1–2 days) after the incident. The severe category, indicative of life-threatening strangulation, was characterized by the presence of petechial haemorrhages, which may occur with or without accompanying loss of consciousness. Given that up to 11%-16% of fatal strangulations (21, 27) cases have been documented without external injuries, caution is warranted when relying solely on such criteria for assessment.

Radiology exams are often reserved for individuals with more severe injuries, and this may also have influenced the higher percentage of petechial haemorrhages in retrospective studies incorporating radiology exams in their analysis (37, 42, 45, 46). The time frame between the assault and the examination may also have influenced the numbers of petechial haemorrhages described in these papers as it is known that these are time sensitive and can be difficult to diagnose after 48 hours.

The presence of petechial hemorrhages must be determined by a trained professional, typically a forensic pathologist, as these can be missed due to their small size or mistaken for other intradermal bleedings. The presence of petechial haemorrhages in self-reported symptoms/survey studies are rarely specified (35, 53, 59, 65, 66). However, Wilbur et al reported that 54% (22/41) of the individuals described tiny red spots albeit, not detailed where (51).

Research on neuropathology together with self-reported brain injury screening indicate that repeated choking events may cause altered cognitive functions (48, 49, 55-57, 67). The results suggest that experiencing choking or strangulation during sexual activity may affect the allocation of neural resources involved in cognitive function (55-57). Although the studies are small, they may indicate that strangulation affects the brain in a way that might have repercussions on the brains ability to process information.

The included studies with data on homicidal fatal strangulations lack a uniform way to define strangulation or report findings, making aggregation of data difficult. The various ways findings are reported may indicate local differences in their assessment, even though findings such as petechiae, bleeding in the neck muscles and fractures of the larynx and hyoid bones hold a special significance. There is a certain degree of circular reasoning in studies where the reported findings form the basis for the diagnosis of strangulation, i.e., making the findings self-reinforcing rather than evidence-based.

Also, the definition of strangulation differs slightly between the studies and in a few studies, it is unclear which definition has been applied. It is worth noting that certain findings, such as facial congestion, show significant variation across studies. While interobserver reliability has not been formally studied, it may contribute to the discrepancies in reported prevalence, as previously suggested (22). Additionally, the transient nature of facial congestion, which can resolve by the time of autopsy, likely plays a role in these variations. Only a few of the included studies report the presence of ethanol and drugs in blood samples from the deceased, however there is no clear conclusion on how such substances may have impacted the fatal outcome of the strangulation event (19, 20, 27).

Several studies have explored various approaches, including radiologic imaging techniques and pathophysiological biomarkers, as supporting evidence to aid in the diagnosis of

strangulation (Table 1 and Table 4). Both PMCT and MRI were shown to provide supporting evidence in strangulation investigations. The strength of CT lies more in the detection of subtle bone lesions. However, this advantage comes with the drawback of radiation exposure to the neck, which includes radiosensitive structures like the thyroid gland and the method is therefore more useful in diseased individuals. MRI offers to reveal internal injuries also in cases without external findings and is more suitable for cases of non-fatal strangulation due to its avoidance of ionizing radiation.

The use of biomarkers for pulmonary or brain pathophysiological findings like aquaporins, heatshock proteins or S100 and GFAP for diagnostic purposes in single cases is challenging due to the lack of established baseline levels. The available supporting studies on this topic are limited, and the existing evidence does not allow for definitive conclusions at this point. However, histological examination of the larynx may reveal fractures of the cricoid cartilage and hemorrhages in the surrounding soft tissues, and can further assist in determining signs of vitality, such as the presence of inflammatory reactions. A potentially promising biochemical approach to supporting the diagnosis of fatal strangulation, as investigated by Palmiere et al., involves the observation of significantly elevated levels of thyroglobulin, total T3, and free T3 in blood samples collected from areas adjacent to the thyroid gland in individuals subjected to strangulation (9). However, these findings are derived from a limited dataset of only four cases and require further investigation to validate their applicability. The diagnosis of strangulation at autopsy remains a combination of external and internal findings as well as circumstances.

Limitations

A scoping review does not include an evaluation of risk of biases, which may allow for potential biases to influence the conclusions. The collected information is primarily derived from

uncontrolled retrospective studies, which are unlikely to follow consistent protocols for assessing and documenting injuries resulting from strangulation. There were few articles available on homicidal strangulation victims defining strangulation in the same way or reporting findings in a uniform way, thereby limiting conclusions. In the reviewed studies, strangulation was often described as a part of other forms of violence, making it difficult to analyse the signs and symptoms associated with non-fatal strangulation events. In addition, individual case reports were intentionally excluded from this review to maintain a broader perspective and enhance the generalizability of the findings. As a result, it is possible that additional symptoms of strangulation, not captured in the reviewed studies, may be described in isolated case reports.

Conclusion

The findings from the reviewed studies highlight the complex and multifaceted nature of strangulation, both in consensual and non-consensual contexts. Strangulation events range from no injury to severe injuries and death. Objective findings are common but not universal, with their detection influenced by study design, victim selection, and the time between the assault and examination. Fatal cases without external injuries (up to 16%) highlight the need for caution in assessing severity based solely on visible signs. Imaging techniques like PMCT and MRI can provide valuable support in strangulation investigations. Most studies of non-fatal strangulation focus on victims of IPV or SA and highlight that strangulation is a common feature of such violence. Emerging evidence suggests that repeated strangulation events has potential effects on brain function, though further research is needed. The exact critical threshold where strangulation becomes life-threatening is not possible to define and call for a consensus approach in medico-legal assessments. These findings underline the importance of

detailed medical records capturing subjective findings, along with high-quality photographic or radiographic documentation, combined with detailed police reports outlining the sequence of events, for medico-legal implications of such cases. Also, the time frame between the alleged assault and the physical examination is crucial to detect objective findings in these individuals.

Ethical approval

Not applicable

Declaration of Competing Interest

The authors declare no conflict of interest.

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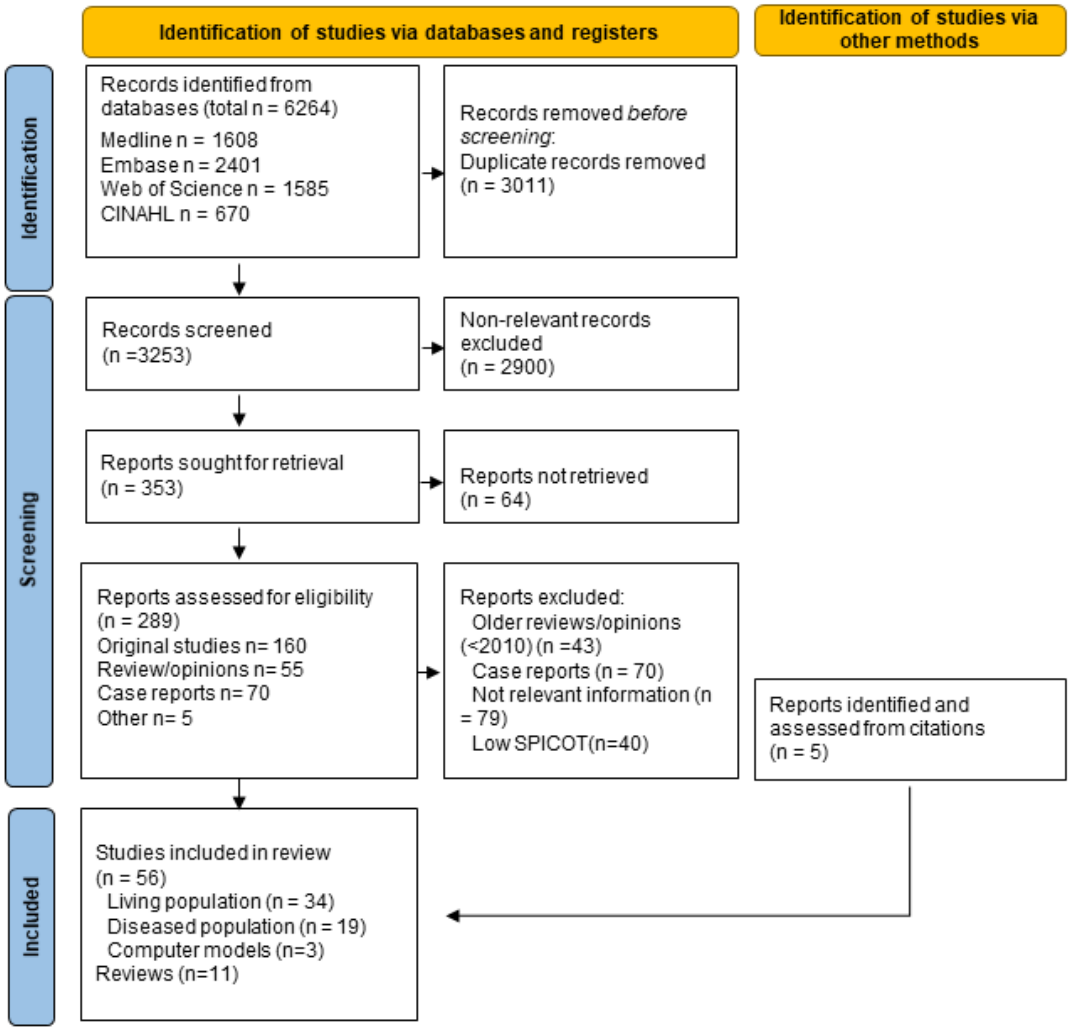
Figures

Figure 1. Flowchart detailing study search and selection



Tables

Table 1. Characteristics from studies examining fatal strangulation

Reference	Aim	Study design	Age and gender distribution	Time between event and autopsy	Circumstances of the event*	Under influence of substance	Survival time after event
Palmiere et al 2018** (12)	To investigate the postmortem stability of thyroglobulin, iodothyronines, calcitonin, and parathyroid hormone in blood.	Retrospective Ancillary evidence study. Strangulation N=4	-	PMI <48h	-	-	-
Li et al 2010** (13)	To investigate morphology of astrocytes in the hippocampus and serum S100B levels in cases of mechanical asphyxia due to neck compression and compare with those of other types of asphyxiation.	Retrospective Case-control Ancillary evidence study. Strangulation N=16	Median 46 years (range 14-93 years) Gender distribution (female:male 9:7)	PMI 7,5-42h strangulation PMI 7,2-48h control	-	-	0,5h Strangulation 0,5-3h Control
Klysner et al 2011** (14)	To determine if abnormal distension of alveolar airspaces is present in fatal strangulations and if so, whether it is consistent enough to support the diagnosis of strangulation.	Retrospective Case-control Ancillary evidence study. Strangulation N=33	Females, Mean 43 years, Median 42 years (range 18-87 years) Males: 17-65 years, Mean 51 years, Median 44 years (range 17-65 years) Gender distribution (female:male 22:11)	-	-	-	-
Fieguth et al 2003** (15)	To investigate if laryngeal haemorrhages occur in cases of strangulation and whether these lesions are specific to strangulation.	Retrospective Case-control Ancillary evidence study. Strangulation N=30	Mean 38 years (range 7-89 years) Gender distribution (female:male 20:10)	-	-	-	-
Tellewar et al 2017 (20)	To profile findings of fatal compression of neck which could help to distinguish between	Prospective Case-control Strangulation N=12 (9 homicides)	(range up to 82 years) Gender distribution (female:male 5:7)	-	-	-	No data about strangulation. Controls: 43/46 dead on the site, 2/46 survived

	hanging and strangulation						>12h, 1 survived <12h.
Wang et al 2012** (17)	To investigate the intrapulmonary expression of aquaporines (AQP-1 and AQP-5) in alveolar epithelial cells in forensic autopsy cases of mechanical asphyxiation due to neck compression compared with sudden cardiac death and brain injury.	Retrospective Case-control Ancillary evidence study. Strangulation N=24	Median 63 years (range 8-87 years) Gender distribution (female:male 11:13)	PMI <48h	-	-	10-37h Mix strangulation 13-46h Control
Härm et al 1981 (23)	Injuries of victims of strangulation were analyzed and compared with the injuries of their assailants.	Retrospective Strangulation N=37 deceased (N=102 survivors)	2Mean 31 years (range 2-76 years) Gender distribution (female:male 26:11)	-	Domestic (60 %) Sexual assault (38%)	BAC N=15/37 (41%) Drugs N= 4/37 (11%)	Considered but not reported
Harruff et al 2023 (24)	To investigate changes in incidence over an extended time and correlate injury patterns with demographics, circumstances, perpetrators, and motivations of the fatal assaults.	Retrospective Strangulation females only N=143	Mean 36 years (range 0-70 years) Gender distribution (female:male 143:0)	-	Sexual assault N=39 (27%) Domestic N=36 (25%)	-	-
Bockholdt et al 2002 (28)	To compare occurance of tongue bleedings in cases of homicidal strangulation and suicidal hanging.	Retrospective Strangulation N=42	-	-	-	-	-
Hlavaty et al 2017 (29)	To examine patterns of injuries in strangulation cases and identify additional traumatic injuries that contributed to the death	Retrospective Strangulation N=43	Mean 38,4 years (range 5-72 years) Gender distribution (female:male 27:16)	-	-	BAC N=15/43 (35%) Cocaine, morphine or other drug alone or in combination N=18/43 (42%)	<24h

Thomsen et al 2022 (3)	Focus on autopsy findings in 250 strangulation victims.	Retrospective Strangulation N=204	Mean 36,8 years, Median 36 years (range 0-87 years) Gender distribution (female:male 170:80)	-	Domestic	-	<54h
Decker et al 2018** (18)	To explore the value of PMCT in evaluation of strangulation fatalities	Literature study Ancillary evidence study. Strangulation N=20	-	-	-	-	-
Demirci et al 2009 (21)	Evaluation of cases of ligature strangulation from a medicolegal aspect	Retrospective Strangulation N=20	Mean 37,2 years (range 1,5-70 years) Gender distribution (female:male 10:10)	-	Homicides 17/20 (85%) Suicides 3/20 (15%) Sexual assault 4/17 (24 %)	-	-
Quan et al 2001** (16)	To evaluate the medico-legal significance of the immuno-histochemical staining of ubiquitin in the midbrain for the diagnosis of fatal acute mechanical asphyxiation and drowning.	Retrospective Ancillary evidence study. Mechanical asphyxia N=18 whereof strangulation N=9	Mean 65,2 years (range 43-85 years) Gender distribution (female:male 6:3)	strangulation 15-50h	-	-	Strangulation <30 min-1.5h
Pollanen et al 1996 (25)	To compare the case profiles and xeroradiographic appearance of the hyoids of 20 victims of homicidal strangulation.	Retrospective Strangulation N=20	Gender distribution (female:male 17:3)	-	-	-	-
Ma et al 2016 (22)	Explore the characteristics of hanging and ligature strangulation.	Retrospective strangulation N=178 (homicide (170) N=141 hangings	(range 0-93 years) Gender distribution (female:male 129:49)	-	Sexual assault 2/170 (1%)	Etanol N= 9/178 (5%) Drugs N=2/178 (1%) Hypnotics N= 7/178 (4%)	-
Godin et al 2012 (26)	To evaluate the fracture of the cricoid cartilage as a potential pointer toward homicide.	Retrospective N= 231 suicides N=4 homicidal hangings N=52 strangulations	-	-	-	-	-

Maxeiner et al 2003 (27)	To report internal autopsy findings of deaths due to strangulation	Retrospective strangulation N=19 suicide N=47 homicide	Females: Mean 50 years (range 16-89 years) Males:, Mean 49 years (range 0-81 years) Gender distribution (female:male 21:26)	-	-	-	-
Maxeiner et al 1998** (19)	To demonstrate that the usual method of laryngeal dissection carries a significant risk of overlooking important laryngeal injuries.	Prospective Ancillary evidence study. strangulation N=191	-	-	-	-	-

PMCT= postmortal computer tomography
PMI= postmortem interval
BAC= blood alcohol concentration

**Circumstances including in a sexual context, voluntary or not, intimate partner violence, repeated occasions etc.*
***Studies examining supporting methods*

Table 2. Focus and number of studies examining fatal strangulation

Focus of study	Number of studies	References
Supporting evidence (biochemical, histology, mRNA expression, CT etc.)	8	(12-19)
Characterizing external and internal findings	6	(3, 20-24)
Characterizing hyoid/thyroid/cricoid fractures and soft tissue hemorrhages	5	(22, 25-28)
Competing causes of death	1	(29)

Table 3. Reported frequency of findings from studies examining fatal strangulation

Parameter	Reported frequency	References
External finding		
-Petechial haemorrhages skin, face or eyes	75%-95%	(3, 20, 22-24, 29)
-Damage to oral mucosa	43%	(3)
-Congestion of face	17%-100%	(3, 20, 22, 29)
-Bruising or marks neck or face	67%-85%	(3, 23, 24, 29)
-Absence of external neck injuries	11%-16%	(24, 29)
Internal findings		
-Haemorrhages/ecchymosis soft tissue	44%-95%	(3, 21, 22, 24, 29)
-Fractures hyoid, thyroid cartilage or cricoid	16%-65%	(3, 21-24, 26, 29)
-Hemorrhages or bitemarks tongue	25%-53%	(27, 28)
-Absence of internal neck injuries in cases of ligature strangulation	"less than 20%"	(27)

Table 4. Characteristics from studies examining non-fatal strangulation

Reference	Aim	Study design	Population size	Age and gender distribution	Time between event and exami-tion	Circumstances of the event*	Under influence of substance
Stellpflug et al 2022 (55)	To describe major injuries and symptoms in non-fatal strangulation and explore use of advanced imaging,	Retrospective.	Strangulation N=130	Mean age 30,6 years (median age 28,5) Gender distribution (female: male 129:1)	Median 13h +/- 42h	Sexual assault	-
Bergin et al 2022 (54)	To describe characteristics of strangulation events in women.	Retrospective	Strangulation N=345	Mean age 32 years (range 15-77 years) Gender distribution (female: male 345:0)	N=313 (90.7%) <4 days N=11 (3.2%) 5 -7 days N=10 (2.9%) 8 -14 days N=11 (3.2%) >14 days	IPV	-
Campbell et al 2018 (65)	To examine the prevalence of probable traumatic brain injury and CNS symptoms in strangulated women.	Retrospective Case-control Self-reported symptoms.	Strangulation N=194 Controls N=358	Median age of participants 27 Gender distribution (female: male 543:0)	Self-reported <2 years.	IPV	-
Cimino et al 2019 (52)	To examine the prevalence of probable traumatic brain injury and its association with comorbid posttraumatic stress syndrome and depression among women.	Retrospective	Strangulation N=95	Mean age 28.8 years Gender distribution (female: male 95:0)	Self-reported <1 year.	IPV	-
Dams-O'Connor et al 2023 (66)	Evaluate the use of the brain injury screening questionnaire IPV module to detect brain injury in an IPV setting.	Retrospective Case-control Self-reported symptoms.	Completed BISQ-IPV N=142 Completed Core BISQ (controls) N=156 N=233 unique individuals	Mean age 53,1 years Sex at birth (% female) N= 53 (37.3%) Gender identity (% female) N= 50 (35.2%) Mean age 57,9 years	-	IPV	-

				Sex at birth (% female) N/A Gender identity (% female) N= 58 (37.2%)			
Daugherty et al. 2022 (59)	To analyse brain alterations in female survivors of IPV and assess the potential causal mechanisms associated with such alterations.	Retrospective Case-control	Strangulation N=27 Controls N=28	Mean age 40 years (range 21-62) Gender distribution (female: male 27:0)	-	IPV	-
Härm et al 1981 (23)	The injuries of 79 surviving and 37 dead victims of strangulation were analyzed.	Retrospective	Strangulation N=79	Maltreatment: age range 5-64 years Rape: age range 14-43 years	-	Assault N=64 Sexual assault N=15	-
Herbenick et al 2022 (35)	To describe the prevalence of ever having choked/been choked as part of sex and examine the characteristics of the events	Retrospective self-reported symptoms	Population N=4242	Mean age 22.2 years (18–67 years) Men: N= 2104 (49.7%) Women N= 2041 (48.2%) Age is missing for 935 (22.0%)	-	Sexual context. consensual	-
Hou et al 2023** (57)	To explore neurophysiological differences between a choking group and a choking naive group by assessments of localized neural activity and connectivity	Retrospective Case-control Supporting evidence study	Strangulation N=20, Controls N=21	Mean age: 21.1 years Gender distribution (female: male 20:0)	< 30 days	Sexual context consensual	AUDIT-score for cases 5.85 +– 4.44
Hou et al 2023** (56)	To examine which brain regions differ between the choking and chokingnaïve control group and analyse the volumetric and geometric features.	Retrospective Case-control Supporting evidence study	Strangulation N=20, Controls N=21	Mean age: 21.1 years Gender distribution (female: male 20:0)	< 30 days	Sexual context consensual	AUDIT-score for cases 5.85 +– 4.44

Huibregtse et al 2022** (58)	To evaluate the impact of frequent exposure to sexual strangulation on working memory in young adult women	Retrospective Case-control Supporting evidence study	Strangulation N=20, Controls N=18/20	Median age: 21 years Gender distribution (female: male 20:0)	< 30 days	Sexual context consensual	AUDIT-score for cases 5.85 +– 4.44
Zuberi et al 2019** (41)	To evaluate the use of computed tomography angiography of the neck to identify strangulation injuries	Retrospective study Supporting evidence study	Strangulation N=142	Mean age: 32.6 years (18–71 years) Gender distribution (female: male 116:26)	-	-	-
Zilkens et al 2016 (43)	To describe the prevalence, risk factors, signs and symptoms of non-fatal strangulation in women following recent sexual assault.	Prospective	Strangulation N=79	13-19 years N=10 (3%) 20-29 years N=33 (8,1%) 30-39 years N=28 (15,1%) >39 years N=8 (5,9%) Gender distribution (female: male 79:0)	<10 days	Sexual assault	-
Yen et al 2007** (39)	To examine non-fatal strangulation victims with MRI to detect internal injuries	Prospective Supporting evidence study	Strangulation N=14	Mean age: 32,6 years (19-45 years) Gender distribution (female: male 12:2)	3-300 h	Mix	-
Bauer et al 2024** (44)	To assess detection of injuries after strangulation with repeated MRI	Prospective Supporting evidence study	Strangulation N=20	Mean age: 33 years (21-50 years) Gender distribution (female: male 15:5)	0-2 days MRI <12 days	-	-
Wilbur et al 2001 (53)	To determine the incidence of strangulation occurrence in domestic violence and describe the experienced subjective symptoms	Prospective Survey study	Strangulation N=42	Age > 18 years Gender distribution (female: male 42:0)	< 2 weeks	IPV	-
White et al 2021 (45)	To determine the prevalence of non-fatal strangulation after a report of sexual assault and describe the prevalence of various	Retrospective	Strangulation N=204	Mean age: 28 years (18-61 years) Median age: 25 years Gender distribution (female: male 197:7)	N=92 (45%) <24h N=49 (24%) 25-48h N=21 (10%) 49-72h N=20 (10%) 73-120h	Sexual assault	-

	symptoms and signs				N=10 (5%) >5-14 days		
Bruguier et al 2020** (46)	To compare objective lesions in non-fatal strangulation victims to those reported from neck-MRI described in medicolegal reports	Retrospective Supporting evidence study	Strangulation N=112 MRI evaluation N=11	Median age: 48 years, (5–85 years) Gender distribution (female: male 93:19)	3- 336h (median 24h) between assault and clinical examination 24-120 h (median 48 h) between assault and MRI	-	-
Christe et al 2010** (47)	To examine findings to differentiate between life-threatening and non-life-threatening strangulation, and to compare clinical and MRI findings of the neck.	Prospective Supporting evidence study	Strangulation N=56	Median age: 26,5 years, (15–54 years) Gender distribution (female: male 35:21)	Median 9.5 h (mean 20.4 h)	-	-
Valera et al 2022 (51)	To examine the relationship between strangulation related alterations in consciousness and cognitive and psychological outcomes in women who have experienced intimate-partner violence.	Retrospective	Strangulation N=52	Age range 18-55 years Gender distribution (female: male 52:0)	-	IPV	No
Christe et al 2009** (61)	To determine objective radiological signs of danger to life in survivors of manual strangulation and to establish a radiological scoring system for the differentiation between life-threatening and	Prospective Supporting evidence study	Strangulation N=56	Median age: 26,5 years, (15–54 years) Gender distribution (female: male 35:21)	Median 9.5 h (mean 20.4 h) MRI median 38 h (mean 50 h)	-	-

	non-life-threatening strangulation.						
Heimer et al 2019** (48)	To provide an overview of MRI findings following nonfatal strangulation.	Prospective Supporting evidence study	Strangulation N=114	Mean age: 32,5 years (16-70 years) Median 29,7 years Gender distribution (female: male 90:24)	Mean 14.3 h, MRI Mean 48.3 h	-	-
Shields et al 2010 (49)	Description of mechanism and findings in non-fatal strangulation victims	Retrospective	Strangulation N=102	Mean age: 31,2 years (17-68 years) Gender distribution (female: male 101:1)	-	IPV or domestic 95 (93%) Assault 7 (7%)	-
Brady et al 2023 (49, 67)	Assessment of findings in non-fatal strangulation victims documented by officers short after the event.	Retrospective	Strangulation N=133	-	-	IPV	-
Ruder et al 2023** (62)	To assess the accuracy of CT and MRI reports of alert patients presenting after non-self-inflicted strangulation.	Retrospective Supporting evidence study	Strangulation N=116	Mean age: 33,8 years (16–75 years) Median 30 years Gender distribution (female: male 82:34)	-	IPV 53% Assault 35% ND 12%	-
Reckdenwald et al 2022 (38)	To examine forensic documentation of non-fatal strangulation in domestic violence cases.	Retrospective	Strangulation N=63	Gender distribution (female: male 61:2)	N=47 (75%) < 24 h N=8 (13%) 24-48 h N=7 (11%) >48 h	IPV	-
Plattner et al 2005 (40)	To examine if findings and symptoms of victims could be related to the fierceness of the assault and the mode of strangulation.	Retrospective	Strangulation N=134	< 18 years N=4 (3%) > 18 years N=130 (97%) Gender distribution (female: male 114:20)	-	sexual assault (35%)	-
McQuown et al 2016 (50)	To identify the prevalence of strangulation in survivors of sexual assault and domestic violence and to identify presence of	Retrospective	Strangulation N=351	Mean age: 30 years (13-98 years). Gender distribution (female: male 97%:3%)	N=148 (43%) <12 h N=58 (16%) >72 h	IPV Sexual assault	

	lethality risk factors.						
Matusz et al 2020 (42)	To define the rate of serious injuries in non-fatal strangulation victims and determine which symptoms and examination findings, if any, predict such injuries.	Retrospective	Strangulation N=328	Median age: 29 (24–37 years) Gender distribution (female: male 309:19)	-	-	-
Marty et al 2022** (60)	To evaluate the potential value of MRI in the examination of non-fatal strangulation.	Retrospective Supporting evidence study	Strangulation N=50 Controls=10	Median age: 28,3 (16–57 years) Gender distribution (female: male 39:11)	<72h after the event	-	-
Linton et al 2024** (37)	To describe experience managing patients who suffered non-fatal strangulation.	Retrospective Supporting evidence study	Strangulation N=86	Mean age: 29,8 years. Gender distribution (female: male 82:4)	N= 49/86 (57%) <24 h N= 22/86 (26%) 24-48 h N= 15/86 (17%) >48 h	-	-
Linkletter et al 2010 (34)	To study postings of partial asphyxiation by adolescents on YouTube and to increase awareness of this dangerous activity as well as the value of YouTube as a research tool.	Retrospective	Strangulation N= 65 (asphyxiation game)	<18 (12-18 years) N=35 (54%) >18 years n=30 (46%) Gender distribution: male (n = 99 participants in videos (90%).	-	-	-
Sharman et al 2024 (36)	To establish the prevalence of strangulation during sex and examine predictors of positive perceptions toward sexual strangulation in Australia.	Confidential, cross-sectional online surveys	N=4701	Age: 18–35 years Mean age: 27.30 Gender distribution (female: male 2241: 2377 TGD: 44)	-	Sexual context. consensual	-

Rossen et al 1943 (63)	To study the effect of acute cerebral anoxia in man, using an apparatus producing arrest of cerebral circulation by means of a cervical pressure cuff.	Prospective	N=136	Age, 17-31 Gender distribution (female:male 0:136)	Immediate	-	-

IPV= intimate partner violence
MRI= magnetic resonance imaging
CT= computer tomography
**Circumstances including event in a sexual context, voluntary or not, intimate partner violence, repeated occasions etc.*
***Studies examining supporting methods*

Table 5. Focus and number of studies examining non-fatal strangulation

Focus of study	Number of studies	References
Intimate partner violence (IPV)	9	(38, 51-54, 59, 65-67)
Sexual assault	3	(43, 45, 55)
IPV and assault	6	(23, 39, 40, 49, 50, 62)
Consensual	5	(35, 36, 56-58)
Supporting evidence (MRI, CT, Otolaryngology)	9	(37, 41, 42, 44, 46-48, 60, 61)
Other	2	(34, 63)

Table 6. Reported frequency of findings from studies examining non-fatal strangulation

Parameter	Reported frequency	References
Objective findings, neck, face or eyes		
-Petechial haemorrhages (face, eyes neck)	1%-28%	(23, 37-49, 53, 55)
-Swelling (neck)	1%-57%	(35, 37, 38, 40-43, 45, 47-49, 53, 55)
-Bruising (neck)	13%-68%	(23, 35, 37, 38, 40-50)
- Erythema/abrasions (neck)	16%-68%	(37, 40, 43-45, 47-49, 53, 55)
Objective findings, laryngea		
-Bleeding	14%- 21%	(39, 61)
-Oedema	14%,	(39)
-Fracture	0% - 5%	(48, 54, 61, 62)
Subjective findings, neurological symptoms		
-Pain (neck)	18%-81%	(35, 37-43, 45, 48, 49, 53-55)
-Visual complaints	1.5%-51%	(37, 39, 42, 43, 45, 47, 53-55)
-Tinnitus	1%-28 %	(37, 53, 54)
-Loss/alteration of consciousness	1%-55%	(23, 37-41, 43-45, 47-50, 53-55), (34, 35, 42, 51, 52)
-Dizziness	9%-72 %	(35, 37, 42, 43, 47, 49, 53, 54)
-Bowel or urinary incontinence	1.3% -15%	(35, 37, 38, 40, 41, 43, 45, 47, 48, 50, 53, 54)
-Neurophysiological/cognitive effects	4%-31%	(38, 50, 53, 54, 56-58)
Subjective findings, pharyngeal or oesophageal symptoms		
-Dysphagia	4%-44%	(37, 38, 41-45, 47-50, 53, 54)
-Dysphonia	0.5%-51%	(37, 38, 41-45, 47, 48, 50, 53-55)
-Dyspnoea	7%-85%	(37, 38, 40-44, 47-50, 53, 54)